Modeling and Simulation of a Dynamic Voltage Restorer

(DVR)

A Project Report Submitted in partial fulfillment of the requirements for the degree of
Bachelor of Technology in Electrical Engineering

by

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CERTIFICATE

This is to certify that the project entitled "**Modeling and Simulation of a Dynamic Voltage Restorer (DVR)**"submitted by **Mr. Amit Kumar Jena** (Roll no. 10602059), **Mr. Bhupen Mohapatra** (Roll no. 10602016) and **Mr. Kalandi Pradhan** (Roll no. 10602018) in partial fulfillment of the requirements for the award of **Bachelor of Technology Degree** in **Electrical Engineering** at **NIT Rourkela**, is an authentic work carried out by them under my supervision and guidance.

Date:

Place: Rourkela

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LIST OF ABBREVIATIONS

APF	Active Power Filters
BESS	Battery Energy Storage Systems
CBEMA	Computer Business Equipment Manufacturers Association
DSC	Distribution Series Capacitors
DSTATCOM	Distribution Static Compensator
DVR	Dynamic Voltage Restorer
FACTS	Flexible AC Transmission Systems
GTO	Gate Turn-Off thyristors
Hz	Hertz
IEC	International Electro technical Commission
IEEE	Institute of Electrical and Electronics Engineers
IGBT	Insulated Gate Bipolar Transistors
IGCT	Integrated Gate Commutated Thyristors
IPAC	In-phase Advanced Compensation
KV	kilovolt
MOSFET	Metal Oxide Semiconductor Field Effect Transistors
ms	mili second
MVA	megavolt ampere
MVAR	mega volt amps reactive
MW	megawatt
p.u.	Per unit
PCC	point of common coupling

PWM	Pulse Width Modulation
RMS	root mean square
SA	Surge Arresters
SCADA	Supervisory Control And Data Acquisition
SEMI	Semiconductor Equipment and Materials International
SETC	Static Electronic Tap Changers
SMES	Superconducting Magnet Energy Storage
SSB	Solid State breaker
SSFCL	Solid State Fault Current Limiter
SSTS	Solid State Transfer Switch
SVC	Static Var Compensator
TSC	Thyristor Switched Capacitors
UPQC	Unified power quality conditioner
UPS	Uninterruptible Power Supplies
VSC	Voltage Source Converter

ABSTRACT

Power quality is one of major concerns in the present era. It has become important, especially, with the introduction of sophisticated devices, whose performance is very sensitive to the quality of power supply. Power quality problem is an occurrence manifested as a nonstandard voltage, current or frequency that results in a failure of end use equipments. One of the major problems dealt here is the power sag.

To solve this problem, custom power devices are used. One of those devices is the Dynamic Voltage Restorer (DVR), which is the most efficient and effective modern custom power device used in power distribution networks. Its appeal includes lower cost, smaller size, and its fast dynamic response to the disturbance. This paper presents modeling, analysis and simulation of a Dynamic Voltage Restorer (DVR) using MATLAB. In this model a PI controller and Discrete PWM pulse generator was used.

CHAPTER-1

INTRODUCTION

1.1 Introduction

1. INTRODUCTION:

1.1 Introduction

Nowadays, modern industrial devices are mostly based on electronic devices such as programmable logic controllers and electronic drives. The electronic devices are very sensitive to disturbances and become less tolerant to power quality problems such as voltage sags, swells and harmonics. Voltage dips are considered to be one of the most severe disturbances to the industrial equipments.

Voltage support at a load can be achieved by reactive power injection at the load point of common coupling. The common method for this is to install mechanically switched shunt capacitors in the primary terminal of the distribution transformer. The mechanical switching may be on a schedule, via signals from a supervisory control and data acquisition (SCADA) system, with some timing schedule, or with no switching at all. The disadvantage is that, high speed transients cannot be compensated. Some sags are not corrected within the limited time frame of mechanical switching devices. Transformer taps may be used, but tap changing under load is costly.

Another power electronic solution to the voltage regulation is the use of a dynamic voltage restorer (DVR). DVRs are a class of custom power devices for providing reliable distribution power quality. They employ a series of voltage boost technology using solid state switches for compensating voltage sags/swells. The DVR applications are mainly for sensitive loads that may be drastically affected by fluctuations in system voltage.

CHAPTER-2

POWER QUALITY PROBLEMS

2.1 Sources and effects of power quality problems

2.2 Standards Associated with Voltage Sags

2.3 Solutions to power quality problems

2. POWER QUALITY PROBLEMS

2.1 Sources and effects of power quality problems:

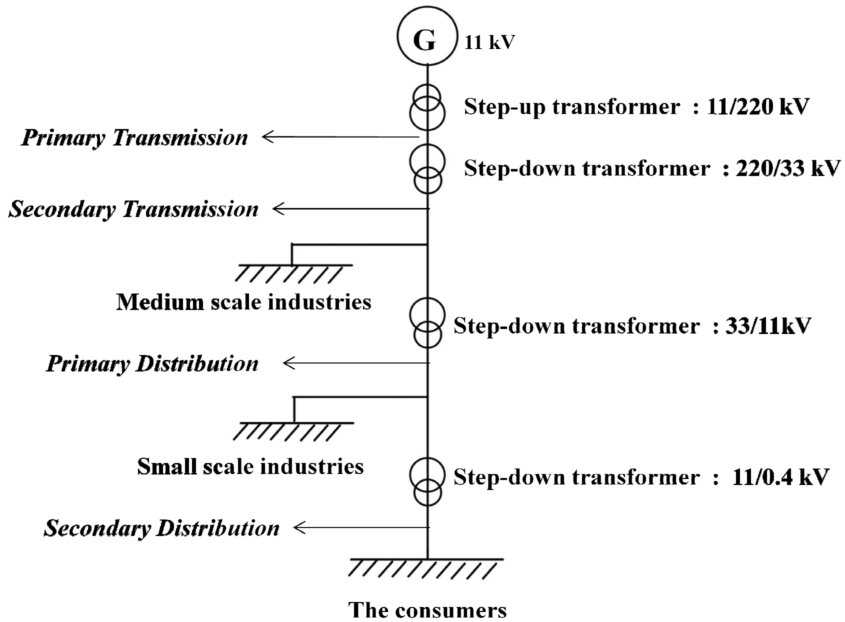

Fig. 2.1 Single line diagram of power supply system

Power distribution systems, ideally, should provide their customers with an uninterrupted flow of energy at smooth sinusoidal voltage at the contracted magnitude level and frequency. However, in practice, power systems, especially the distribution systems, have numerous nonlinear loads, which significantly affect the quality of power supplies. As a result of the nonlinear loads, the purity of the waveform of supplies is lost. This ends up producing many power quality problems.

While power disturbances occur on all electrical systems, the sensitivity of today's sophisticated electronic devices makes them more susceptible to the quality of power supply. For some sensitive devices, a momentary disturbance can cause scrambled data, interrupted communications, a frozen mouse, system crashes and equipment failure etc. A power voltage spike can damage valuable components. Power Quality problems encompass a wide range of disturbances such as voltage sags/swells, flicker, harmonics distortion, impulse transient, and interruptions.

- *Voltage dip:* A voltage dip is used to refer to short-term reduction in voltage of less than half a second.
- *Voltage sag:* Voltage sags can occur at any instant of time, with amplitudes ranging from 10 – 90% and a duration lasting for half a cycle to one minute.
- *Voltage swell:* Voltage swell is defined as an increase in rms voltage or current at the power frequency for durations from 0.5 cycles to 1 min.
- *Voltage 'spikes', 'impulses' or 'surges'*: These are terms used to describe abrupt, very brief increases in voltage value.
- *Voltage transients:* They are temporary, undesirable voltages that appear on the power supply line. Transients are high over-voltage disturbances (up to 20KV) that last for a very short time.
- *Harmonics: The fundamental frequency* of the AC electric power distribution system is 50 Hz. A *harmonic frequency* is any sinusoidal frequency, which is a multiple of the *fundamental frequency.* Harmonic frequencies can be even or odd multiples of the sinusoidal fundamental frequency.
- *Flickers:* Visual irritation and introduction of many harmonic components in the supply power and their associated ill effects.

2.1.1 Causes of dips, sags and surges:

1. Rural location remote from power source
2. Unbalanced load on a three phase system
3. Switching of heavy loads
4. Long distance from a distribution transformer with interposed loads
5. Unreliable grid systems
6. Equipments not suitable for local supply

2.1.2 Causes of transients and spikes:

1. Lightening
2. Arc welding
3. Switching on heavy or reactive equipments such as motors, transformers, motor drives
4. Electric grade switching

2.2 Standards Associated with Voltage Sags

Standards associated with voltage sags are intended to be used as reference documents describing single components and systems in a power system. Both the manufacturers and the buyers use these standards to meet better power quality requirements. Manufactures develop products meeting the requirements of a standard, and buyers demand from the manufactures that the product comply with the standard.

The most common standards dealing with power quality are the ones issued by IEEE, IEC, CBEMA, and SEMI.

2.2.1 IEEE Standard

The Technical Committees of the IEEE societies and the Standards Coordinating Committees of IEEE Standards Board develop IEEE standards. The IEEE standards associated with voltage sags are given below.

IEEE 446-1995, “IEEE recommended practice for emergency and standby power systems for industrial and commercial applications range of sensibility loads”

The standard discusses the effect of voltage sags on sensitive equipment, motor starting, etc. It shows principles and examples on how systems shall be designed to avoid voltage sags and other power quality problems when backup system operates.

IEEE 493-1990, “Recommended practice for the design of reliable industrial and commercial power systems”

The standard proposes different techniques to predict voltage sag characteristics, magnitude, duration and frequency. There are mainly three areas of interest for voltage sags. The different areas can be summarized as follows:

- Calculating voltage sag magnitude by calculating voltage drop at critical load with knowledge of the network impedance, fault impedance and location of fault.
- By studying protection equipment and fault clearing time it is possible to estimate the duration of the voltage sag.
- Based on reliable data for the neighborhood and knowledge of the system Parameters an estimation of frequency of occurrence can be made.

IEEE 1100-1999, "IEEE recommended practice for powering and grounding Electronic equipment"

This standard presents different monitoring criteria for voltage sags and has a chapter explaining the basics of voltage sags. It also explains the background and application of the CBEMA (ITI) curves. It is in some parts very similar to Std. 1159 but not as specific in defining different types of disturbances.

IEEE 1159-1995, "IEEE recommended practice for monitoring electric power quality"

The purpose of this standard is to describe how to interpret and monitor electromagnetic phenomena properly. It provides unique definitions for each type of disturbance.

IEEE 1250-1995, "IEEE guide for service to equipment sensitive to momentary voltage disturbances"

This standard describes the effect of voltage sags on computers and sensitive equipment using solid-state power conversion. The primary purpose is to help identify potential problems. It also aims to suggest methods for voltage sag sensitive devices to operate safely during disturbances. It tries to categorize the voltage-related problems that can be fixed by the utility and those which have to be addressed by the user or equipment designer. The second goal is to help designers of equipment to better understand the environment in which their devices will operate. The standard explains different causes of sags, lists of examples of sensitive loads, and offers solutions to the problems.

2.2.2 SEMI International Standards

The SEMI International Standards Program is a service offered by Semiconductor Equipment and Materials International (SEMI). Its purpose is to provide the semiconductor and flat panel display industries with standards and recommendations to improve productivity and business. SEMI standards are written documents in the form of specifications, guides, test methods, terminology, and practices. The standards are voluntary technical agreements between equipment manufacturer and end-user.

The standards ensure compatibility and interoperability of goods and services. Considering voltage sags, two standards address the problem for the equipment.

SEMI F47-0200, “Specification for semiconductor processing equipment voltage sag immunity”. The standard addresses specifications for semiconductor processing equipment voltage sag immunity. It only specifies voltage sags with duration from 50ms up to 1s. It is also limited to phase-to-phase and phase-to-neutral voltage incidents, and presents a voltage-duration graph, shown in Figure 2.2. SEMI F42-0999, “Test method for semiconductor processing equipment voltage sag immunity”

This standard defines a test methodology used to determine the susceptibility of semiconductor processing equipment and how to qualify it against the specifications. It further describes test apparatus, test set-up, test procedure to determine the susceptibility of semiconductor processing equipment, and finally how to report and interpret the results.

2.3 Solutions to power quality problems:

There are two approaches to the mitigation of power quality problems. The solution to the power quality can be done from customer side or from utility side First approach is called load conditioning, which ensures that the equipment is less sensitive to power disturbances, allowing the operation even under significant voltage distortion. The other solution is to install line conditioning systems that suppress or counteracts the power system disturbances. Currently they are based on PWM converters and connect to low and medium voltage distribution system in shunt or in series. Series active power filters must operate in conjunction with shunt passive filters in order to compensate load current harmonics. Shunt active power filters operate as a controllable current source and series active power filters operates as a controllable voltage source. Both schemes are implemented preferable with voltage source PWM inverters, with a dc bus having a reactive element such as a capacitor. However, with the restructuring of power sector and with shifting trend towards distributed and dispersed generation, the line conditioning systems or utility side solutions will play a major role in improving the inherent supply quality; some of the effective and economic measures can be identified as following:

Lightening and Surge Arresters:

Arresters are designed for lightening protection of transformers, but are not sufficiently voltage limiting for protecting sensitive electronic control circuits from voltage surges.

Thyristor Based Static Switches:

The static switch is a versatile device for switching a new element into the circuit when the voltage support is needed. It has a dynamic response time of about one cycle. To correct quickly for voltage spikes, sags or interruptions, the static switch can used to switch one or more of devices such as capacitor, filter, alternate power line, energy storage systems etc. The static switch can be used in the alternate power line applications.

Energy Storage Systems:

Storage systems can be used to protect sensitive production equipments from shutdowns caused by voltage sags or momentary interruptions. These are usually DC storage systems such as UPS, batteries, superconducting magnet energy storage (SMES), storage capacitors or even fly wheels driving DC generators .The output of these devices can be supplied to the system through an inverter on a momentary basis by a fast acting electronic switch. Enough energy is fed to the system to compensate for the energy that would be lost by the voltage sag or interruption.

Though there are many different methods to mitigate voltage sags and swells, but the use of a custom Power device is considered to be the most efficient method. For example, Flexible AC Transmission Systems (FACTS) for transmission systems, the term custom power pertains to the use of power electronics controllers in a distribution system, specially, to deal with various power quality problems. Just as FACTS improves the power transfer capabilities and stability margins, custom power makes sure customers get pre-specified quality and reliability of supply. This pre-specified quality may contain a combination of specifications of the following: low phase unbalance, no power interruptions, low flicker at the load voltage, low harmonic distortion in load voltage, magnitude and duration of overvoltage and under voltages within specified limits, acceptance of fluctuations, and poor factor loads without significant effect on the terminal voltage There are many types of Custom Power devices. Some of these devices include: Active Power Filters (APF), Battery Energy Storage Systems (BESS), Distribution STATic synchronous COMpensators (DSTATCOM), Distribution Series Capacitors (DSC), Dynamic Voltage

Restorer (DVR), Surge Arresters (SA), Super conducting Magnetic Energy Systems (SMES), Static Electronic Tap Changers (SETC), Solid-State Transfer Switches (SSTS), Solid State Fault Current Limiter (SSFCL), Static Var Compensator (SVC), Thyristor Switched Capacitors (TSC), and Uninterruptible Power Supplies (UPS).

CHAPTER-3

DYNAMIC VOLTAGE RESTORER (DVR)

3.1 Introduction

3.2 Basic configuration

3.3 Equations related to DVR

3.4 Operating modes

3.5 Voltage injection methods

3. DYNAMIC VOLTAGE RESTORER:

3.1 Introduction:

Among the power quality problems (sags, swells, harmonics…) voltage sags are the most severe disturbances. In order to overcome these problems the concept of custom power devices is introduced recently. One of those devices is the Dynamic Voltage Restorer (DVR), which is the most efficient and effective modern custom power device used in power distribution networks. DVR is a recently proposed series connected solid state device that injects voltage into the system in order to regulate the load side voltage. It is normally installed in a distribution system between the supply and the critical load feeder at the point of common coupling (PCC). Other than voltage sags and swells compensation, DVR can also added other features like: line voltage harmonics compensation, reduction of transients in voltage and fault current limitations.

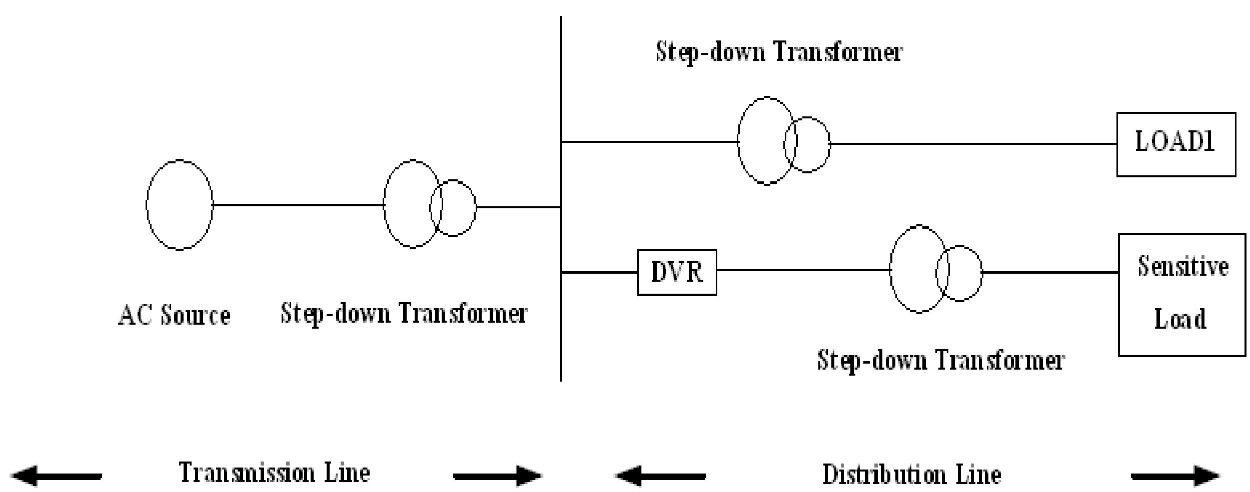

Fig. 3.1: Location of DVR

3.2 Basic Configuration of DVR:

The general configuration of the DVR consists of:

i. An Injection/ Booster transformer

ii. A Harmonic filter

iii. Storage Devices

iv. A Voltage Source Converter (VSC)

v. DC charging circuit

vi. A Control and Protection system

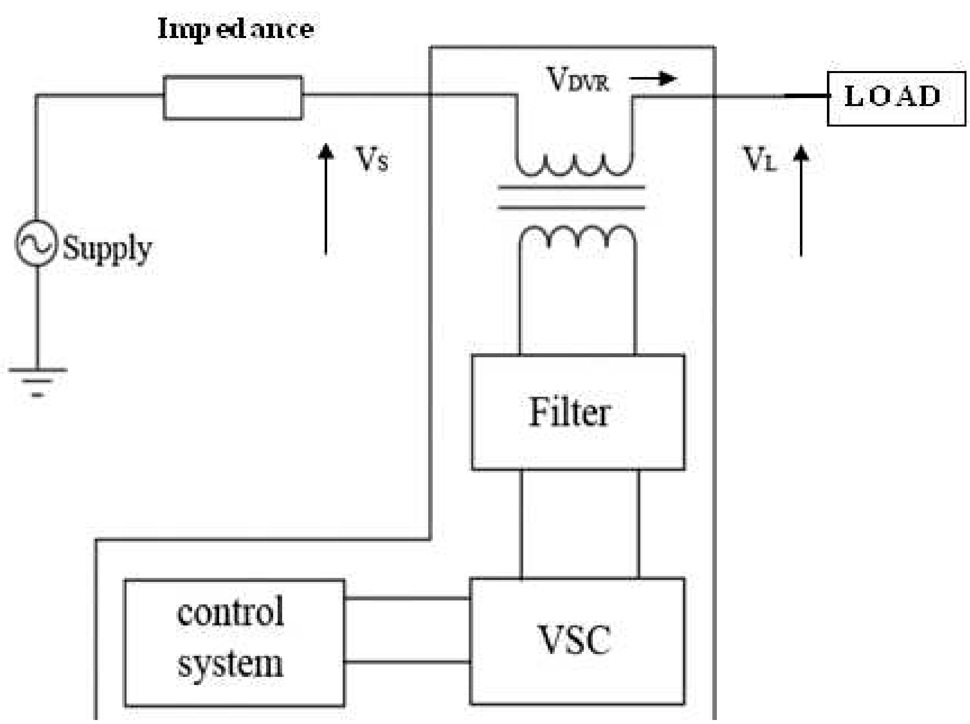

Fig. 3.2: Schematic diagram of DVR

3.2.1 Injection/ Booster transformer:

The Injection ⁄ Booster transformer is a specially designed transformer that attempts to limit the coupling of noise and transient energy from the primary side to the secondary side. Its main tasks are:

- It connects the DVR to the distribution network via the HV-windings and transforms and couples the injected compensating voltages generated by the voltage source converters to the incoming supply voltage.
- In addition, the Injection ⁄ Booster transformer serves the purpose of isolating the load from the system (VSC and control mechanism).

3.2.2 Harmonic Filter:

The main task of harmonic filter is to keep the harmonic voltage content generated by the VSC to the permissible level.

3.2.3 Voltage Source Converter:

A VSC is a power electronic system consists of a storage device and switching devices, which can generate a sinusoidal voltage at any required frequency, magnitude, and phase angle. In the DVR application, the VSC is used to temporarily replace the supply voltage or to generate the part of the supply voltage which is missing.

There are four main types of switching devices: Metal Oxide Semiconductor Field Effect Transistors (MOSFET), Gate Turn-Off thyristors (GTO), Insulated Gate Bipolar Transistors (IGBT), and Integrated Gate Commutated Thyristors (IGCT). Each type has its own benefits and drawbacks. The IGCT is a recent compact device with enhanced performance and reliability that allows building VSC with very large power ratings. Because of the highly sophisticated converter design with IGCTs, the DVR can compensate dips which are beyond the capability of the past DVRs using conventional devices.

The purpose of storage devices is to supply the necessary energy to the VSC via a dc link for the generation of injected voltages. The different kinds of energy storage devices are Superconductive magnetic energy storage (SMES), batteries and capacitance.

3.2.4 DC Charging Circuit:

The dc charging circuit has two main tasks.

- The first task is to charge the energy source after a sag compensation event.
- The second task is to maintain dc link voltage at the nominal dc link voltage.

3.2.5 Control and protection:

The control mechanism of the general configuration typically consists of hardware with programmable logic. All protective functions of the DVR should be implemented in the software. Differential current protection of the transformer, or short circuit current on the customer load side are only two examples of many protection functions possibility.

3.3 Equations related to DVR

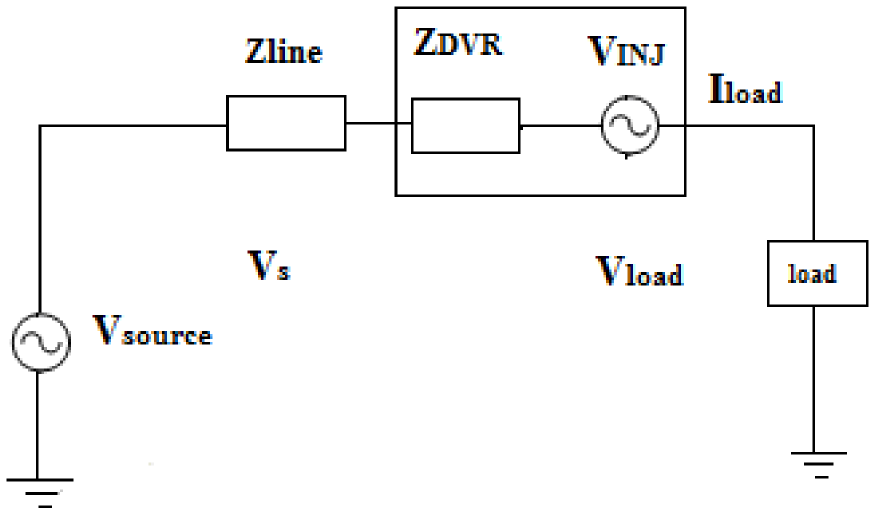

Fig. 3.3 Equivalent circuit diagram of DVR

The system impedance Z_{th} depends on the fault level of the load bus. When the system voltage (V_{th}) drops, the DVR injects a series voltage VDVR through the injection transformer so that the desired load voltage magnitude V_L can be maintained. The series injected voltage of the DVR can be written as

$$\boldsymbol{V_{DVR} = V_L + Z_{TH} I_L - V_{TH}}$$

Where

$\boldsymbol{V_L}$: The desired load voltage magnitude

$\boldsymbol{Z_{TH}}$: The load impedance.

$\boldsymbol{I_L}$: The load current

$\boldsymbol{V_{TH}}$: The system voltage during fault condition

The load current I_L is given by,

$$\boldsymbol{I_L = \frac{[P_L + jQ_L]}{V}}$$

When V_L is considered as a reference equation can be rewritten as,

$$\boldsymbol{V_{DVR}\angle 0 = V_L\angle 0 + Z_{TH}\angle(\beta - \theta) - V_{TH}\angle\delta}$$

$\propto$, β, δ are angles of V_{DVR}, Z_{TH}, V_{TH} respectively and θ is Load power angle

$$\boldsymbol{\theta = tan^{-1}\left(\frac{\theta_L}{P_L}\right)}$$

The complex power injection of the DVR can be written as,

$$\boldsymbol{S_{DVR} = V_{DVR}I_L{}^{*}}$$

It requires the injection of only reactive power and the DVR itself is capable of generating the reactive power.

3.4 Operating modes of DVR:

The basic function of the DVR is to inject a dynamically controlled voltage V_{DVR} generated by a forced commutated converter in series to the bus voltage by means of a booster transformer. The momentary amplitudes of the three injected phase voltages are controlled such as to eliminate any detrimental effects of a bus fault to the load voltage V_L. This means that any differential voltages caused by transient disturbances in the ac feeder will be compensated by an equivalent voltage generated by the converter and injected on the medium voltage level through the booster transformer.

The DVR has three modes of operation which are: protection mode, standby mode, injection/boost mode.

3.4.1 Protection mode:

If the over current on the load side exceeds a permissible limit due to short circuit on the load or large inrush current, the DVR will be isolated from the systems by using the bypass switches (S2 and S3 will open) and supplying another path for current (S1 will be closed).

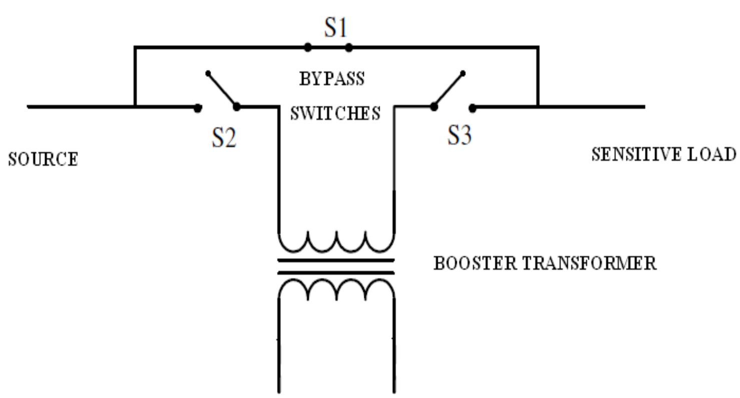

Fig. 3.4: Protection Mode (creating another path for current)

3.4.2 Standby Mode: (V_{DVR}= 0)

In the standby mode the booster transformer's low voltage winding is shorted through the converter. No switching of semiconductors occurs in this mode of operation and the full load current will pass through the primary.

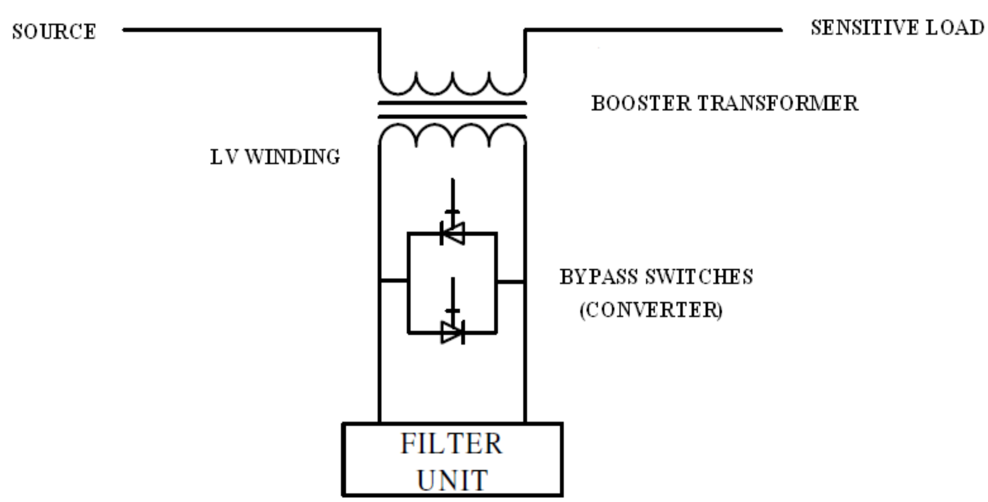

Fig. 3.5: Standby Mode

3.4.3 Injection/Boost Mode: (V_{DVR}>0)

In the Injection/Boost mode the DVR is injecting a compensating voltage through the booster transformer due to the detection of a disturbance in the supply voltage.

3.5 Voltage injection methods of DVR:

Voltage injection or compensation methods by means of a DVR depend upon the limiting factors such as; DVR power ratings, various conditions of load, and different types of voltage sags. Some loads are sensitive towards phase angel jump and some are sensitive towards change in magnitude and others are tolerant to these. Therefore the control strategies depend upon the type of load characteristics.

There are four different methods of DVR voltage injection which are

i. Pre-sag compensation method
ii. In-phase compensation method
iii. In-phase advanced compensation method
iv. Voltage tolerance method with minimum energy injection

3.5.1 Pre-sag/dip compensation method:

The pre-sag method tracks the supply voltage continuously and if it detects any disturbances in supply voltage it will inject the difference voltage between the sag or voltage at PCC and pre-fault condition, so that the load voltage can be restored back to the pre-fault condition. Compensation of voltage sags in the both phase angle and amplitude sensitive loads would be achieved by pre-sag compensation method. In this method the injected active power cannot be controlled and it is determined by external conditions such as the type of faults and load conditions

$$V_{DVR} = V_{prefault} - V_{sag}$$

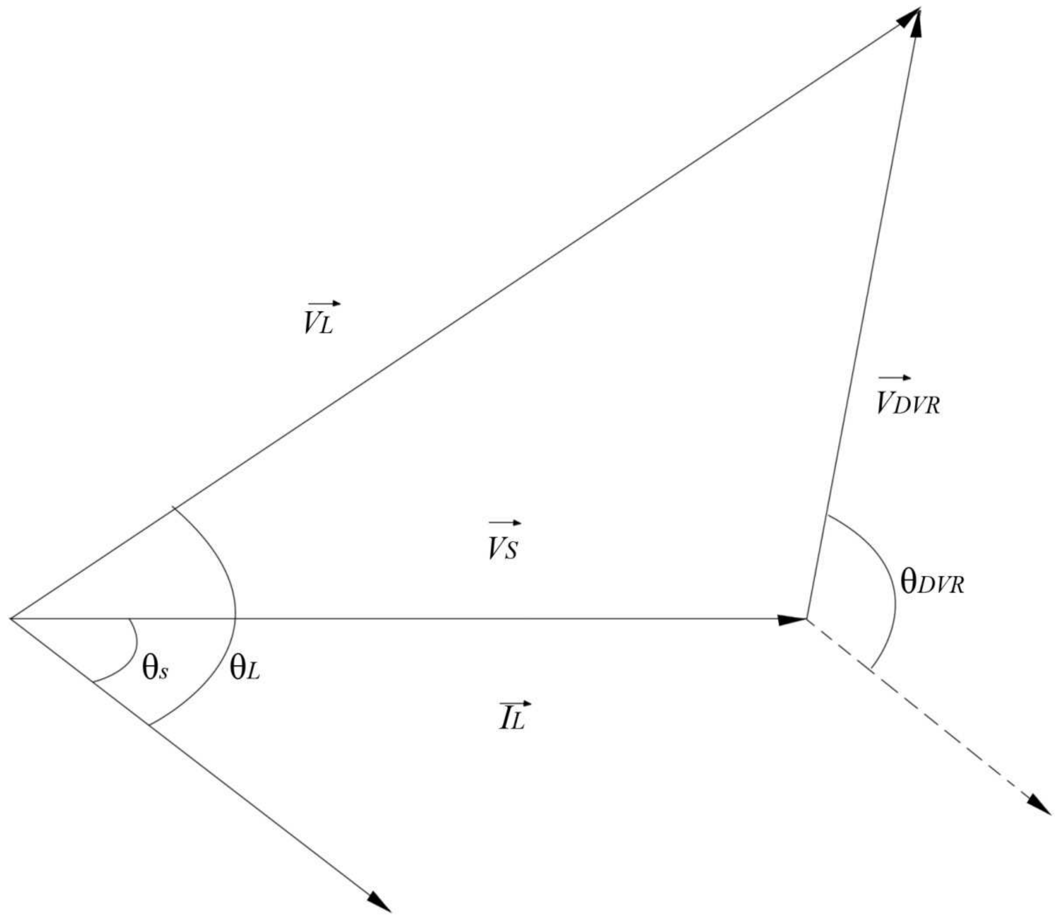

Fig. 3.6: Pre-sag compensation method

3.5.2 In-phase compensation method:

This is the most straight forward method. In this method the injected voltage is in phase with the supply side voltage irrespective of the load current and pre-fault voltage. The phase angles of the pre-sag and load voltage are different but the most important criteria for power quality that is the constant magnitude of load voltage are satisfied.

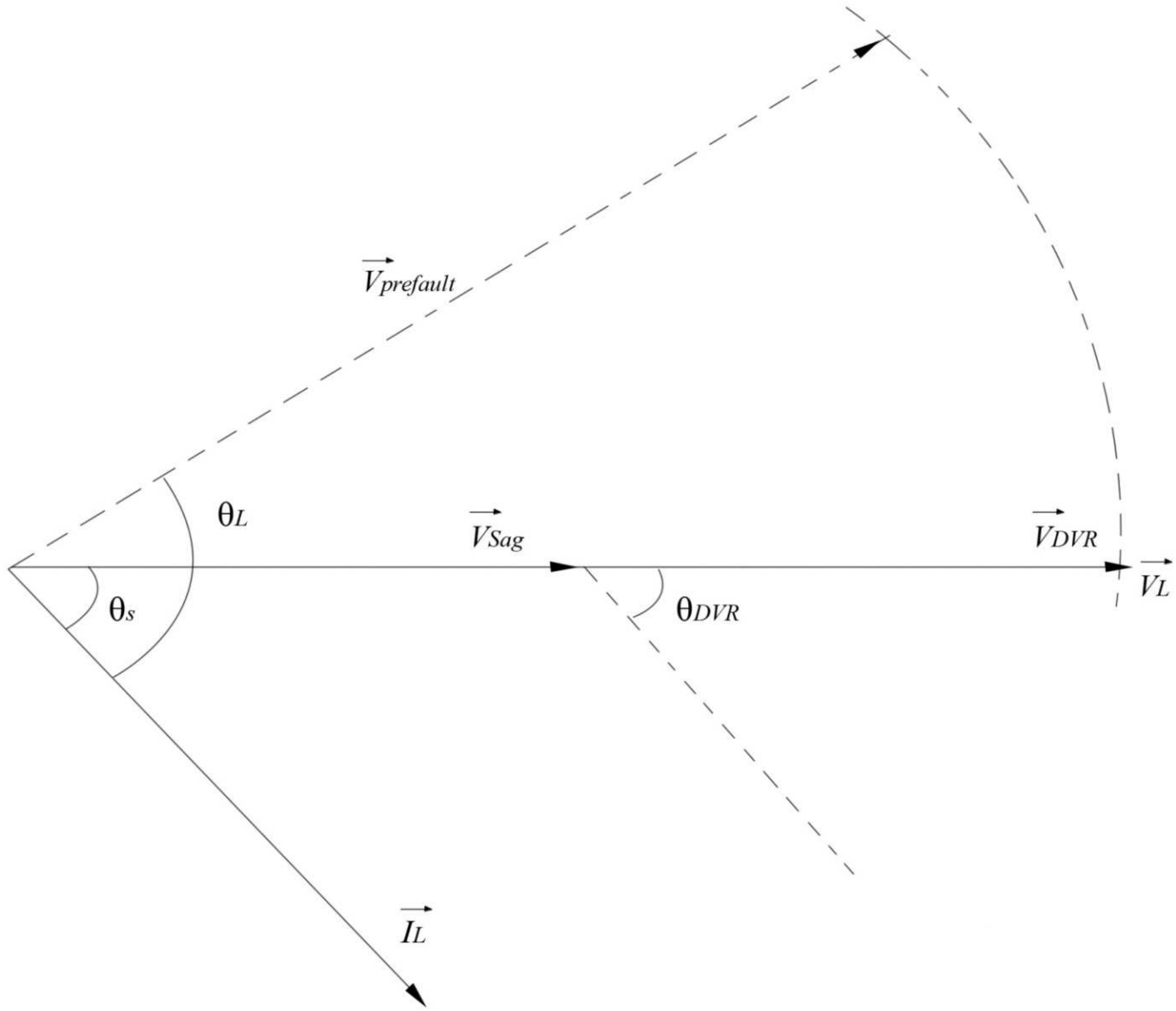

Fig. 3.7: In-phase compensation method

$$|V_L|=|V_{prefault}|$$

One of the advantages of this method is that the amplitude of DVR injection voltage is minimum for a certain voltage sag in comparison with other strategies. Practical application of this method is in non-sensitive loads to phase angle jump.

3.5.3 In-phase advanced compensation method:

In this method the real power spent by the DVR is decreased by minimizing the power angle between the sag voltage and load current. In case of pre-sag and in-phase compensation method the active power is injected into the system during disturbances. The active power supply is limited stored energy in the DC links and this part is one of the most expensive parts of DVR. The minimization of injected energy is achieved by making the active power component zero by having the injection voltage phasor perpendicular to the load current phasor.

In this method the values of load current and voltage are fixed in the system so we can change only the phase of the sag voltage. IPAC method uses only reactive power and unfortunately, not al1 the sags can be mitigated without real power, as a consequence, this method is only suitable for a limited range of sags.

3.5.4 Voltage tolerance method with minimum energy injection:

A small drop in voltage and small jump in phase angle can be tolerated by the load itself. If the voltage magnitude lies between 90%-110% of nominal voltage and 5%-10% of nominal state that will not disturb the operation characteristics of loads. Both magnitude and phase are the control parameter for this method which can be achieved by small energy injection.

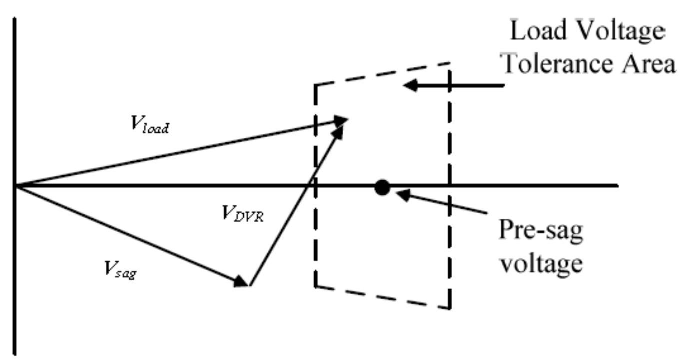

Fig. 3.8: Voltage tolerance method with minimum energy injection

CHAPTER-4

REALIZATION OF COMPENSATION TECHNIQUE

4.1 Discrete PWM-Based Control Scheme

4.2 Test systems

4. REALIZATION OF COMPENSATION TECHNIQUE:

4.1 Discrete PWM-Based Control Scheme

In order to mitigate the simulated voltage sags in the test system of each compensation technique, also to compensate voltage sags in practical application, a discrete PWM-based control scheme is implemented, with reference to DVR. The aim of the control scheme is to maintain a constant voltage magnitude at the sensitive load point, under the system disturbance. The control system only measures the rms voltage at load point, for example, no reactive power measurement is required.

Figure 4.1 shows the DVR controller scheme implemented in MATLAB/SIMULINK. The DVR control system exerts a voltage angle control as follows: an error signal is obtained by comparing the reference voltage with the rms voltage measured at the load point. The PI controller processes the error signal and generates the required angle δ to drive the error to zero, for example; the load rms voltage is brought back to the reference voltage.

It should be noted that, an assumption of balanced network and operating conditions are made. The modulating angle δ or delta is applied to the PWM generators in phase A, whereas the angles for phase B and C are shifted by 240° or -120° and 120° respectively.

$$V_A = Sin\ (\omega t + \delta)$$

$$V_B = Sin\ (\omega t + \delta - 2\pi/3)$$

$$V_C = Sin\ (\omega t + \delta + 2\pi/3)$$

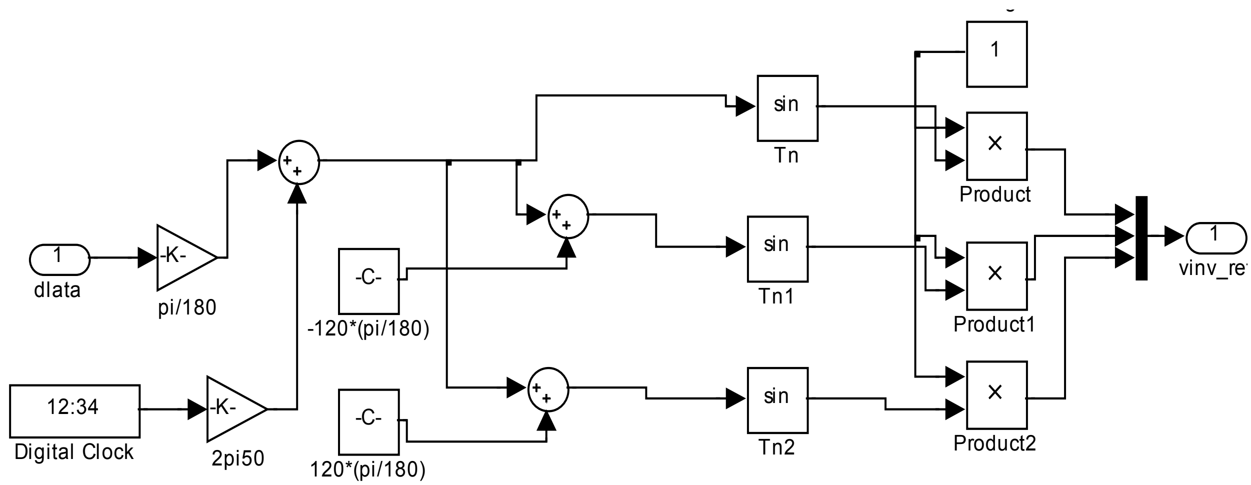

Fig. 4.1: firing angle controller scheme

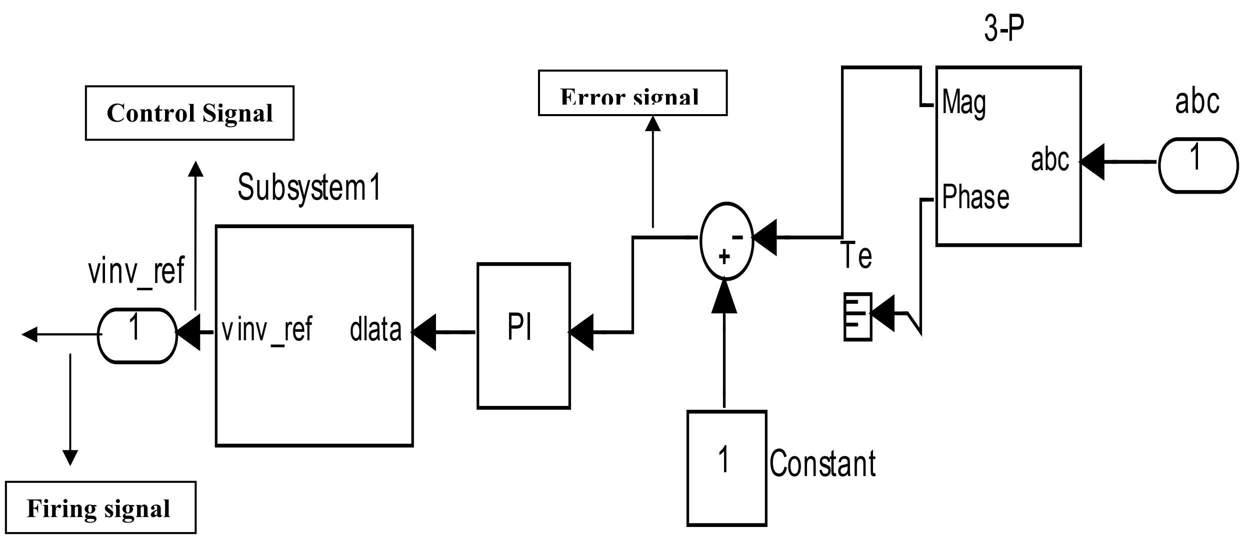

Fig. 4.2: SIMULINK model of DVR controller

4.2 Test system for DVR:

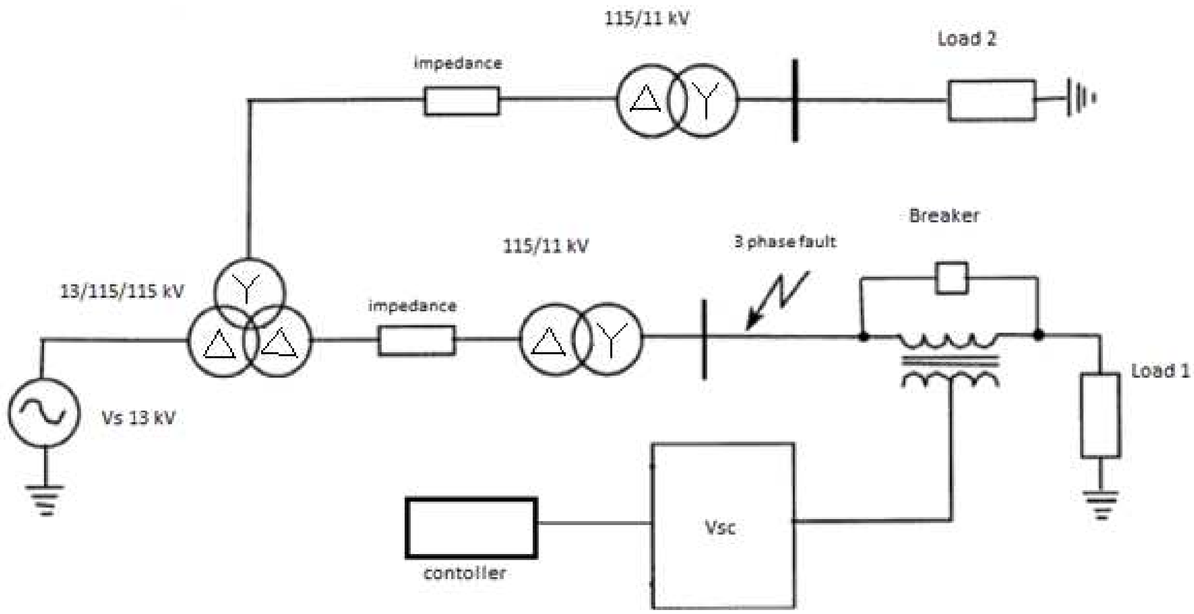

Fig. 4.3 Single line diagram of test system

Single line diagram of the test system for DVR is composed by a 13 kV, 50 Hz generation system, feeding two transmission lines through a 3- winding transformer connected in Y/Δ/Δ, 13/115/115 kV. Such transmission lines feed two distribution networks through two transformers connected in Δ/Y, 115/11 kV. To verify the working of DVR for voltage compensation a fault is applied at point X at resistance 0.66 Ω for time duration of 200 ms. The DVR is simulated to be in operation only for the duration of the fault.

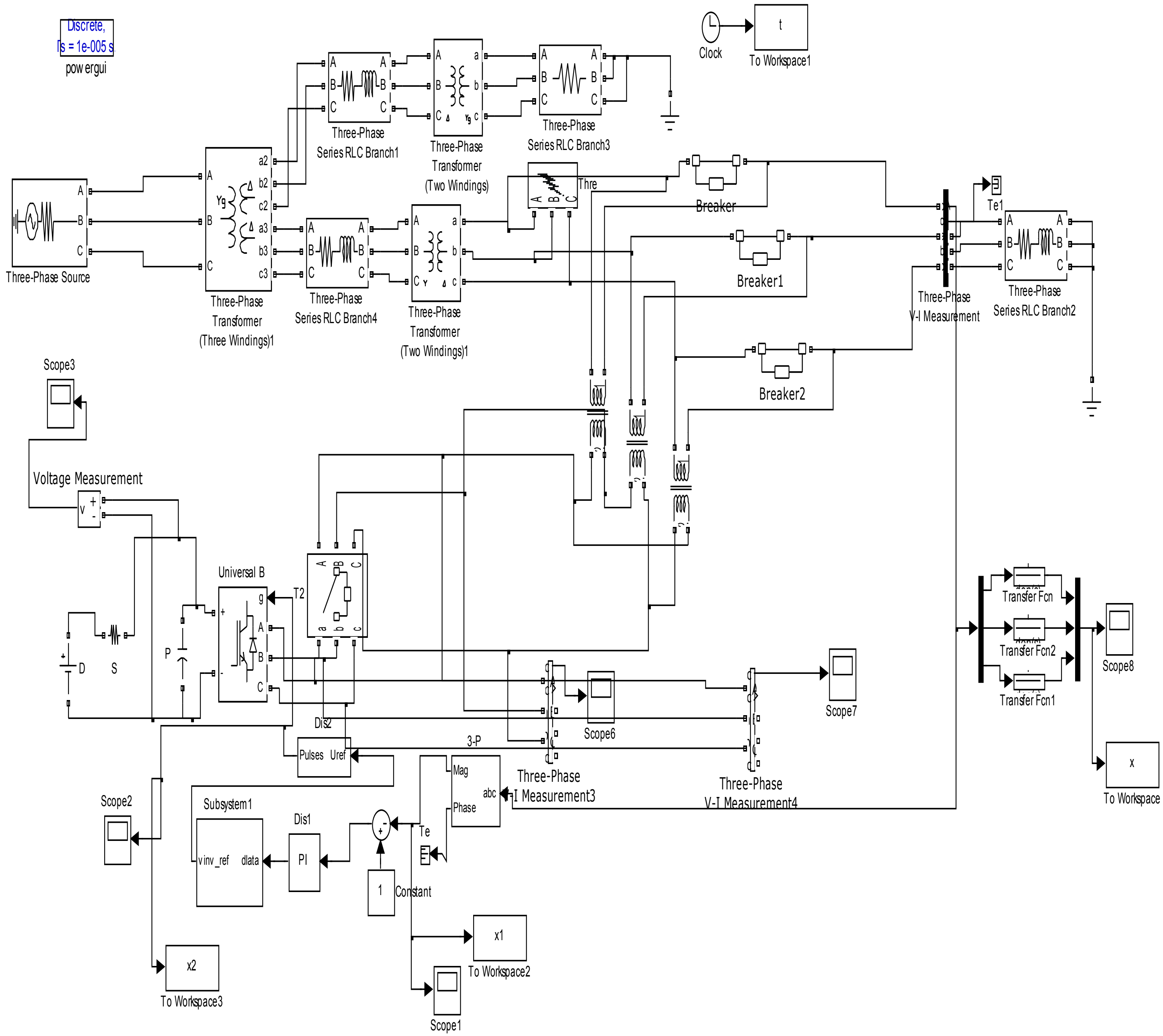

Fig. 4.4: SIMULINK block diagram of DVR

CHAPTER-5

SIMULATIONS AND RESULTS

SIMULATIONS AND RESULTS:

The first simulation was done with no DVR and a three phase fault is applied to the system at point with fault resistance of 0.66 Ω for a time duration of 200 ms. The second simulation is carried out at the same scenario as above but a DVR is now introduced at the load side to compensate the voltage sag occurred due to the three phase fault applied.

Figure 5.1 shows the rms voltage at load point when the system operates with no DVR and a three phase fault is applied to the system. When the DVR is in operation the voltage interruption is compensated almost completely and the rms voltage at the sensitive load point is maintained at normal condition.

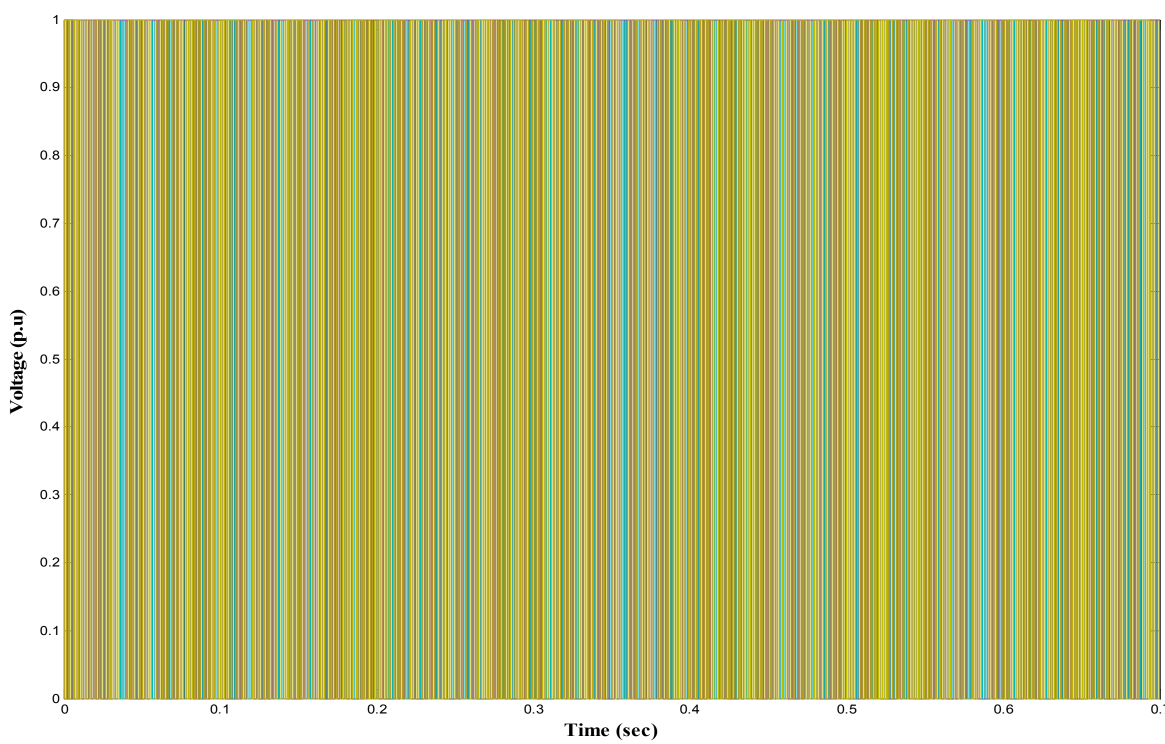

Fig. 5.1: Firing pulse generated by discrete PWM generator

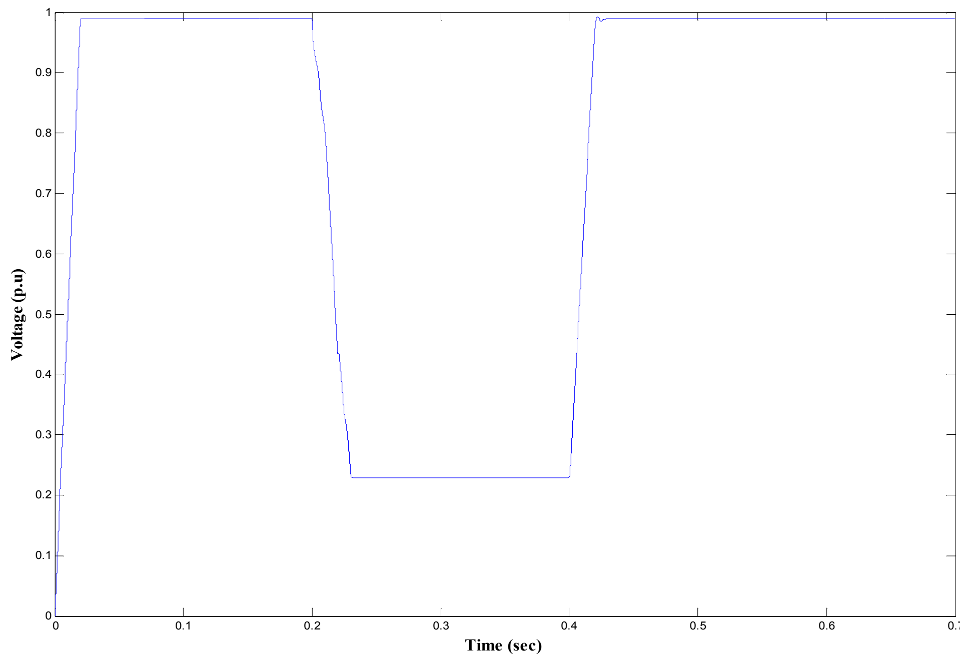

Fig. 5.2: P.U Voltage at load point, with 3-Ø fault, without DVR

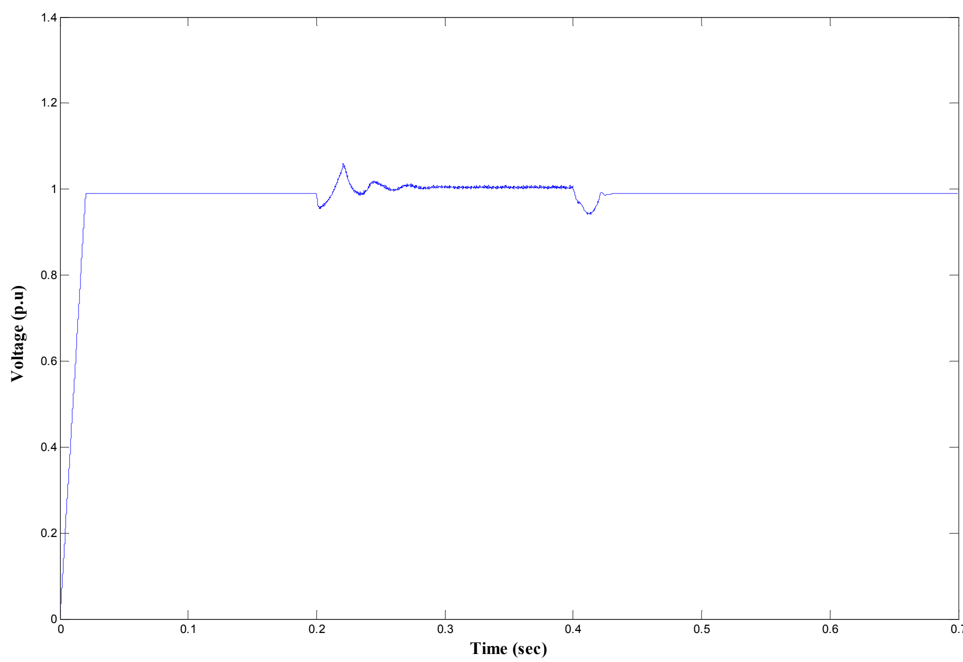

Fig. 5.3: P.U Voltage at load point, with 3-Ø fault, with DVR

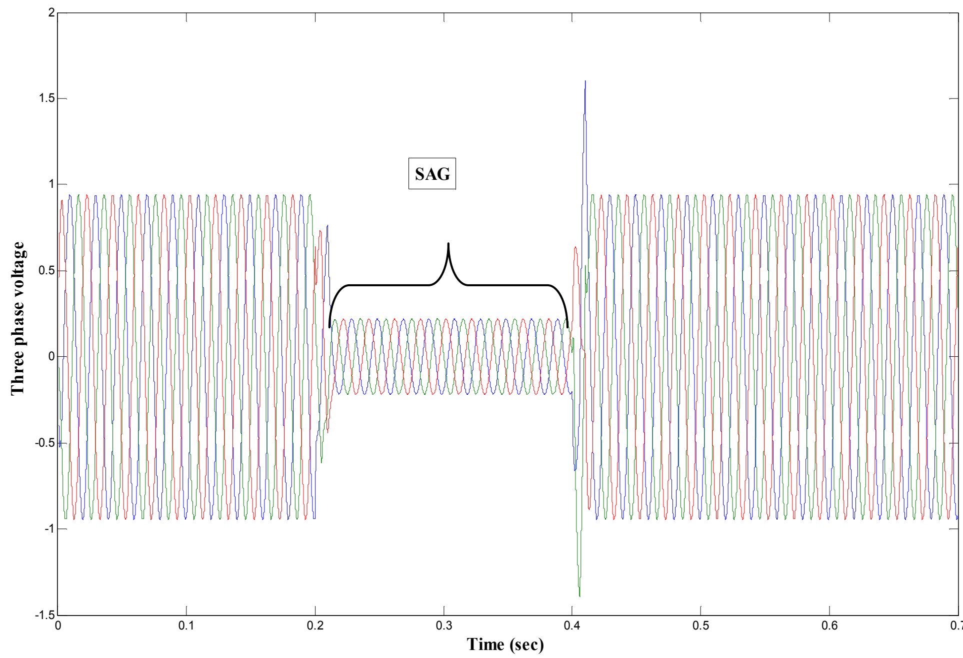

Fig. 5.4: 3-Ø Voltage at load point, with 3-Ø fault, without DVR

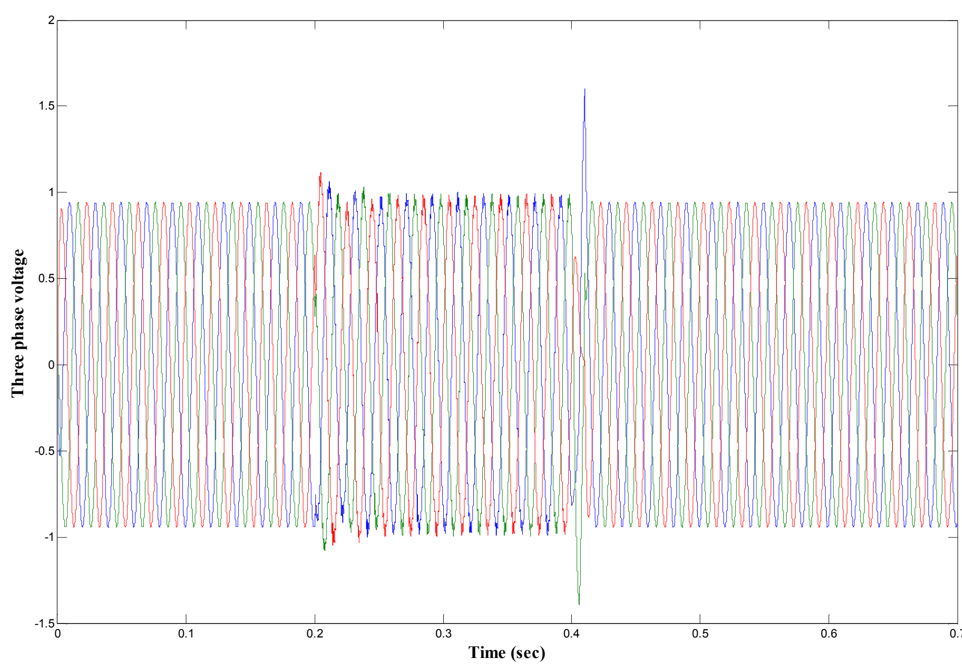

Fig. 5.5: 3-Ø Voltage at load point, with 3-Ø fault, with DVR

CHAPTER-6

CONCLUSION

CONCLUSIONS:

This paper has presented the power quality problems such as voltage dips, swells, distortions and harmonics. Compensation techniques of custom power electronic devices DVR was presented. The design and applications of DVR for voltage sags and comprehensive results were presented. A PWM-based control scheme was implemented. As opposed to fundamental frequency switching schemes already available in the MATLAB/ SIMULINK, this PWM control scheme only requires voltage measurements. This characteristic makes it ideally suitable for low-voltage custom power applications.

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